the discussion. Mr. Sydney F. Walker read a paper on earth in collieries, in which he pointed out some of the difficulties in carrying out the special rules drawn up by the departmental committee for the installation and use of electricity in mines. If earth was to be admitted into the system, the only method of carrying out the wishes of the committee was to use an uninsulated return completely enclosing the live conductor. The last paper read was by Mr. John T. Stobbs on the value of fossil Mollusca in Coal-measure stratigraphy. He expressed the opinion that Mollusca afforded the best means of correlating Coal-measures, and considered that their neglect was due to inadequate collections in public museums, and to the fact that teachers failed to impress upon students the utility of the Mollusca as zonal indices. The Coal-measures were, he thought, comparatively neglected by the geologist, the knowledge of the Ordovician, Silurian, and Chalk systems being much more exact than that of the 3000 feet of Coal-measures. The remaining days of the meeting were devoted to excursions to Chanters Colliery, to New Moss Colliery, to the Manchester Museum, to the works of the British Westinghouse Company and the Manchester Ship Canal, to Pendleton Colliery, and to other places of interest.

THE BRITISH ASSOCIATION.

SECTION K

BOTANY.

OPENING ADDRESS[1] BY HAROLD WAGER, F.R.S., H.M.I., PRESIDENT OF THE SECTION.

ON SOME PROBLEMS OF CELL STRUCTURE AND PHYSIOLOGY.

Introduction.

WHEN Robert Hooke, in the early part of the seventeenth century, discovered, with the aid of his improved compound microscope, the cell structure of plants, he little thought that our ultimate knowledge of the physical and chemical processes in the living organism, of its growth and reproduction, of the problems of heredity and of the factors underlying the origin of life itself, would be in the main dependent upon a clear understanding of the structure and physiology of the cell.

Hooke's researches did not, in fact, carry him very far, and we must turn to the nearly contemporaneous works of Malpighi and Grew on the anatomy of plants for the first clear indication of the important part which cells take in the constitution of the various tissues of plants. The account they give of them is extremely interesting in the light of our present knowledge. Grew, for example, in speaking of the structure of the root, compares the parenchyma to a sponge, "being a body porous, dilative, and pliable . . . a most exquisitely fine wrought sponge." The pores are spherical and consist of "an infinite mass of little cells or bladders. The sides of none of these are visibly pervious from one into another; but each is bounded within itself. . . . They are the receptacles of liquor, which is ever lucid, and . . . always more thin or watery." There is no indication either in Grew's or Malpighi's works that they understood the significance of this cell structure, and it was not until the beginning of the nineteenth century, after a lapse of some 150 years, that any insight into the real nature of the cell and its functions was obtained. But then began a period of activity—associated with the names of Turpin, Meyen, Robert Brown, Purkinje, J. Müller, Henle, Valentin, and Dutrochet—which culminated in the cell theory of Schleiden and Schwann that the common basis of all animal and plant tissues is the cell, and that it is upon this elementary vital unit that all growth and development depends.

The nucleus was discovered in 1831 by Robert Brown in various tissues of the Orchideæ and in some other families of the monocotyledons, as well as in some dicotyledons. He described it as a "single circular areola, generally somewhat more opaque than the membrane of the cell," and more or less granular. It is very distinct and regular in form, and its granular matter is held together by a coagulated pulp not visibly granular, or, which may be considered equally probable, by an enveloping membrane. Although Robert Brown was the first to recognise the importance of the nucleus, and to give it a name, it had been seen by previous observers, and he himself mentions that he had met with indications of its presence in the works of Meyen and Purkinje, chiefly in some figures of the epidermis; in a memoir by Brogniart on the structure of leaves, and that Mr. Bauer had particularly noticed it in the cells of the stigma of *Bletia tankervilliae,* but had associated it with the impregnation by pollen. There are some figures by Leeuwenhoek, published in 1719, to which Prof. L. C. Miall has directed my attention, of blood-corpuscles of a fish, human epidermal cells, and the connective tissue of a lamb, in which nuclei are shown, and they had been seen by Fontana (1781) in epithelial cells, and by Cavolini (1787) in some fishes' eggs.

To Schleiden and Schwann the cell was essentially a membranous vesicle enclosing a fluid sap and a solid nucleus. They thought that it arose in contact with the nucleus as a delicate transparent vesicle which gradually increased in size and became filled with the watery sap. As soon as it was completely formed, the nucleus, having done its work, was either absorbed or cast off as a "useless member," or in some cases was "found enclosed in the cell-wall, in which situation it passes through the entire vital process of the cell which it has formed." So far from being the most important organ of the cell, as we now consider it to be, they saw in the nucleus merely a centre of cell formation which is no longer required when the cell is formed. It was left for Hugo von Mohl to show that the mucus-like contents of the cell which he called protoplasm (1846) is the real living matter in which reside those activities which call into play the phenomena of life, and that the origin of nuclei by division from a nucleus already existing in the parent cell would possibly be found to occur very widely. Von Mohl, Nägeli, and Hofmeister all appear to have had some idea of the importance of the nucleus in cell division. Von Mohl says that the "process is preceded in almost all cases by a formation of as many nuclei as there are to be compartments in the mother-cell." Hofmeister's description of it is interesting: "The membrane of the nucleus dissolves, but its substance remains in the midst of the cell; a mass of granular mucilage accumulates around it: this parts, without being invested by a membrane, into two masses, and these afterwards become clothed with membranes and appear as two daughter-nuclei."

It is, however, mainly to the researches of the last thirty years that we owe our knowledge of the many complex cell-activities at work in living organisms, and we are still only just on the fringe of the great problems which cytology has to solve. Some of the most important of these are the origin and evolution of the nucleus, the meaning of the complex mode in which the nucleus divides, the origin and nature of the spindle figure and centrosomes, the part played by the chromosomes in the transmission of hereditary characteristics, the meaning of the phenomena accompanying fertilisation, the significance of the longitudinal division of the chromosomes and of their reduction in number in the sexual cells, and the evolution of the living substance. The satisfactory solution of these problems depends upon a clear understanding of the structure of protoplasm and its various differentiations. How far we have succeeded in obtaining this I will endeavour to show.

The Differentiation of Structure in the Cell.

The essential constituent of a cell is the protoplasm. This is differentiated into two constituents, the cytoplasm and the nucleus. It is usually held that this differentiation is an essential one, and that these two constituents are present in all cells; but, as we shall see later, there is some evidence that not only are there cells with very rudimentary nuclei, but cells in which no trace of a nuclear structure can be found at all.

In addition to this primary differentiation of the cell, secondary differentiations occur, resulting in the production of organs such as chloroplasts, chromoplasts, leucoplasts, pyrenoids, and pigment spots, which have special functions to perform. All these are permanent organs of the cell, produced in the first instance as a result of the cell activity, but now capable of an independent existence in the cell, in that they reproduce themselves by division, and are in this way carried on from cell to cell.

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[1] Slightly abridged.

In many cells there are formed at certain stages other organs which appear to be transitory, and are only produced when they are required. Such are the spindle figure, the centrosome, the blepharoplast, and the cœnocentrum.

So far as we know, the cell is the smallest vital unit that can have a separate existence. But it is only among the unicellular organisms and under certain conditions in the earlier stages of development of the more highly organised multicellular organisms that cells have a perfectly independent life. Schwann's hypothesis that the multicellular body is a colony of independent vital activities governing the nutrition, growth, and reproduction of the whole is not tenable. The cell cannot be regarded as an independent unity working merely in association with other cells. Its life and existence depend upon these. It is an integral part of an individual organisation, and cannot exist apart from it. But this absolute dependence of individual cells upon the organisation as a whole is only realised in the more highly developed forms. In the lower types of plants (and animals) it is possible, during the early stages of development, to separate a single cell from the whole, which will still continue to live and grow. Each cell is no doubt dependent upon the others to some extent, even at this early stage, but it still retains the power to develop independently if placed under suitable conditions. As cell division continues each cell becomes more and more dependent upon its fellows, until the stage is reached when it no longer has the power to exist by itself. The various functions performed by a cell reside within it as an individual unit, but the exercise of these functions is governed by the organism as a whole. Just as the organism seeks for a state of equilibrium in relation to various external stimuli, so a cell in an organism has to adapt itself to and come into a state of equilibrium with the various cells around it.

The Nucleus.

The nucleus is the centre of activity, and governs the vital functions of the cell. All investigations show that in its absence the cell soon ceases to perform its vital functions and dies.

In all cells, from the algæ and fungi upwards, the nucleus is more or less clearly delimited from the cytoplasm by a membrane or limiting layer. The important substance which is thus separated off from the rest of the cell is the chromatin, probably the most complex and most highly differentiated chemical compound or collection of compounds in the cell. It exists in the form of a more or less granular network, and is characterised chemically by the presence of phosphorus, which is in organic connection with it. We may look upon the chromatin as the highest point in the development of living substance, upon which the activities of the cell in great measure depend, and as the seat of origin of all those complicated changes which have for their ultimate aim the division of the cell.

The division of the nucleus begins by a series of transformations in the chromatin network which lead to the differentiation in it of chromosomes. We know very little of what actually takes place during these changes, and practically nothing of the forces at work to bring them about. But the visible result is that the chromatin granules gradually fuse together, or become restricted to certain areas by the increased vacuolation of the ground substance of the nucleus to form a thick, more or less regular thread, in which can be observed at certain stages a differentiation into alternate regions of stainable and unstainable substance—chromatin and achromatin—which finally breaks up into equal or unequal lengths to form the chromosomes. In some cases the chromatin granules or network become aggregated into a definite number of irregular masses which form the chromosomes directly without the production of a distinct chromatin thread.

This nuclear differentiation is usually accompanied by changes in the cytoplasm which lead to the appearance of a fibrillar structure in the form of a more or less regular spindle, the threads of which come into contact with the chromosomes through the breaking down of the nuclear wall. The chromosomes then, by the action of a force or forces of which we as yet know very little, arrange themselves in regular order in the equatorial plane of the spindle figure, and some of the spindle fibres become attached to them. The chromosomes become divided longitudinally into two apparently exactly equal halves; and then, probably by the exertion of some sort of contractile force or pull on the part of the spindle fibres, the separate halves are caused to move to opposite poles of the spindle. Here a series of transformations take place, which lead to the constitution of two new nuclei. Such are the essential features in this complex process of nuclear division, and it is a striking fact that they occur with more or less regularity in all nuclei from the algæ and fungi up to the highest plants.

The Structure of Cytoplasm.

In the elucidation of cell structure we owe much to the beautiful methods of staining and fixing which are due especially to Flemming and Heidenhain, to the improved micro-chemical methods which we owe especially to Zacharias and Macallum, and to the investigations of such observers as Fischer and Mann, who have shown us the effects of various reagents upon the living substance, and have thus taught us to be very cautious in our interpretations of the structures seen in dead fixed cells.

The investigations of oil-foams and colloids by Butschli, Hardy, and others have given us a clue to possible explanations of the various appearances seen both in the living and dead fixed and stained cells, and the introduction of the ribbon section cutting microtome into the domain of vegetable histology has enabled us to make the best use of the beautiful apochromatic object-glasses which we owe to the researches of the late Prof. Abbe.

It is unfortunate that, so far, very little progress has been made in the examination of the structure of the living cell. We may hope that, with the improved methods of illumination now available, combined with experimental investigation, it will be possible to make some progress in this direction. It is of the greatest importance that we should be able to satisfy ourselves to what extent the various appearances seen in the fixed and stained cell are due to the action of the reagents employed. In this respect a recent discovery by Köhler, which indicates the possibility of making use of the ultra-violet rays in such investigations, is of interest. Köhler (*Phys. Zeit.*, 1904) finds that if the ultra-violet rays from the electric spark between cadmium or magnesium terminals are separated out by means of quartz prisms, objects illuminated by them, when examined by means of lenses made of quartz, show differentiations of structure which otherwise require staining to make them visible. The chromatin of the nucleus and such substances as cuticle and cork are almost opaque to the ultra-violet rays, and can be made visible on a fluorescent screen or can be photographed. The resolving power of the microscope is doubled, and Lummer considers that the principle employed is the only one by which further progress in resolving power can be made. If the method is found by cytologists to be a workable one, it may open up an entirely new field of microscopic investigation by which the protoplasmic differentiation in living cells may be more clearly revealed.

Many attempts have been made to show that the cytoplasm possesses a definite morphological structure of its own, which is related to the various functions it performs, and that it is not a formless semi-viscid fluid in which various physical and chemical forces are at work, and upon which the various structures observed depend; in other words, that it possesses a morphological constitution as opposed to a merely chemical one.

Fromman and Heitzmann in 1875 described the structure of cytoplasm as consisting of fine threads or fibres in the form of a net with fluid between and forming a sponge-like structure. Flemming in 1882 described it as composed of two substances, one in the form of fibrils (filar substance) embedded in the other, a more or less homogeneous interfilar substance. In 1890 Altmans propounded his interesting hypothesis that all living substance is made up of minute granules or bioblasts, which are the real vital units or elementary organism, embedded in a homogeneous substance, the non-living matter. Cells are formed by a combination of these units of a lower order, and are therefore individuals or units of the second order.

At about the same time Butschli brought forward his celebrated hypothesis of the froth or alveolar structure of cytoplasm. This was based upon an extensive series of observations upon both living and dead cells as well as upon froths or foams made by mixing salts of various kinds with oil and then placing small particles of the oily mixtures so obtained in water.

Butschli compares the structure of cytoplasm to that of a fine froth, and considers that much of the granular, and network or fibrillar structure can be referred to the optical appearances presented by such a froth. That such structures are visible cannot be doubted by anyone who has examined these froths attentively with the microscope. But that all the fibrillar structures described by Fromman and Flemming, whose observations have often been confirmed since by competent cytologists, can be referred to a froth structure, cannot, I think, be accepted by anyone who has carefully examined plant cells.

From the fact that cytoplasm appears homogeneous under certain conditions, and that the foam structure can be so readily produced in it by various means, and further that, as Hardy has shown, the action of certain reagents upon colloids results in the separation of solid particles which become linked together to form a comparatively coarse, solid framework in the form of an open net which holds fluid in its meshes, it is probable that we shall find the foam-structure theory of protoplasm is not tenable. It seems far more in accordance with what we know that we should regard protoplasm as fundamentally a semi-fluid, homogeneous mass, in which, by its own activity, granules, vacuoles, fibrils, &c., can be produced as secondary structures; and that any special morphological structure which it may possess is beyond the limits of the present resolving powers of the microscope.

The Structure of the Nucleus.

From the recent observations of Gregoire and Wygaerts, Berghs, Allen, Mano, and others, it is difficult to arrive at any definite conclusions as to the structure of the nucleus, or as to the changes which take place in it leading to the production of the chromosomes. The resting nucleus seems to possess a very simple organisation. In the living condition it appears to consist merely of a homogeneous ground substance in which is contained a mass of chromatin granules which do not appear to have any particular shape, and one larger granule of a spherical shape, the nucleolus. Sometimes a network or foam structure is visible, but not always; but here, as in the cytoplasm, it is difficult to be certain of this. It may be that the chromatin is always in the form of an irregular network embedded in the colourless ground substance, and that the granular appearance is due to an optical effect similar to that observed in finely meshed oil-foams. According to Strasburger, Miss Sargant, Farmer and Moore, Mottier, and others, the nucleus contains an achromatic network—the linin—in which the chromatin granules are embedded. Mano, Moll, and Sypkens deny the existence of these two substances, and state that the network consists of chromatin only; while Gregoire and Wygaerts, Allen and Berghs, are inclined to the view that there is a fundamental basis of linin which is impregnated by chromatin ordinarily diffused through its whole substance, but capable of being collected into certain definite regions under certain conditions by which the granular appearance is produced. The evidence brought forward in many of the more recent investigations certainly goes to show that the chromatin is not in the form of such definite granules as was at one time supposed; that they are not so regular in size or outline; and that it is not easy to differentiate between the chromatin and achromatin contents of the nucleus. Staining reactions do not afford a sound clue to their differentiation, for, as Fischer and, more recently, Allen have shown, the differences in staining reactions of the different parts of the nucleus vary according to the strength of the stain, the time it is allowed to act, and the size or thickness of the granules or threads stained.

Strasburger has suggested that the chromosomes are formed by the fusion of gamosomes (chromatin granules) around gamo-centres into zygosomes (chromosomes), but the changes which take place are probably not so clearly defined as this. What seems clear from the facts we know is that the substance forming the homogeneous chromosomes—the chromatin or nuclein—becomes broken up in the reconstitution of the daughter-nuclei, by vacuolation or otherwise, into an irregular network which presents a granular appearance. In this all trace of the original individual chromosomes is in most cases lost, and at the same time one or more deeply staining bodies of a spherical, or nearly spherical shape—the nucleoli—appear in contact with it.

The Nucleolus and its Function.

The evidence is steadily accumulating that the nucleolus is intimately concerned in the formation of the chromosomes, although probably not exclusively concerned in this function. In most cases it appears to form a part of the chromatin network, being connected to it by threads, and generally gives similar reactions to the chromosomes. In some few cases it is described as completely separated from the network by a clear area which is visible both in the living and in the stained condition. The evidence that the nucleolus is concerned in chromosome formation may be summed up as follows: the nucleoli are closely connected or associated with the nuclear network; as the nuclear network becomes more deeply stained the nucleoli become smaller or lose their capacity for stains; at the time the chromosomes are being differentiated they are connected to the nucleoli by delicate threads; the chromosomes resemble nucleoli in their behaviour towards reagents and stains; during the period of sinapsis the nucleoli come into very close relations with the nuclear thread, and as the nucleus gradually passes out of the sinaptic stage the thread stains more deeply; in the reconstitution of the daughter-nuclei the chromosomes can be seen to fuse together into a more or less irregular mass, out of which the delicate nuclear network and the prominent nucleolus are evolved; in certain cases all the chromatin appears to be stored up in the nucleolus.

It has been suggested that the nucleolar substance is a product of excretion of the nucleolus, but there is very little evidence for this view. On the other hand it is very likely, as suggested by Mottier, that the nucleolus contains a store of nutritive material which can be used up for various purposes, both in the nucleus and in the cytoplasm. In some cells a portion of the nucleolar substance is thrown out into the cytoplasm during the division stages, and it is very probable that this may have some important connection with the metabolic activity of the cell at this period.

Division of the Nucleus in the Spore Mother-cells.

The divisions of the nucleus which lead immediately to the formation of the spores possess some features which are not found in ordinary vegetative mitosis, and which have an important bearing upon the facts of heredity. The first of these is known as the heterotype, the second as the homotype division. The essential features of the heterotypical division are as follows:—The chromatin net becomes gradually resolved into a more or less continuous spireme. This thread (or threads) contracts into an irregular mass around the nucleolus, a phenomenon which was first discovered by Moore, and to which he gave the name of "sinapsis." Some observers regard this contraction as caused by reagents; but since it has been observed in the living condition by Miss Sargant and others, it is probably a definite and normal stage in the division. It is concerned with some very pronounced changes which take place at this time in the nucleus. The nuclear thread becomes more prominent, stains more deeply and exhibits a double row of granules which gives it the appearance of a double thread. This has been variously interpreted by different investigators: Miss Sargant, Farmer and Moore, and many others consider that it is due to a longitudinal splitting of the thread; Dixon, Gregoire, Berghs, and Allen consider it as indicating a close approximation of separate loops of the thread. Whichever of these explanations is the correct one, the doubling gradually disappears and the thread becomes distributed through the nuclear cavity and again appears single; it becomes shorter and thicker and once more becomes aggregated around the nucleolus. This may be, as Miss Sargant suggests, a second sinapsis. At this stage the chromosomes appear, but reduced to half the number of those which appeared in the previous divisions, so that they may be regarded as bivalent or double chromosomes. They become shorter and thicker, and gradually become grouped in the equatorial plane of the nucleus, where they become attached to the spindle fibres. Each chromosome now divides into two halves, which pass to the respective poles of the spindle, to form, without the intervention of a complete resting stage, the division figures of the daughter-nuclei.

The exact mode in which the division of the chromosomes into two halves takes place is the subject of much controversy. The studies of Weissman on the phenomena of heredity led him to the conclusion that the chromosomes consist of more than one complete ancestral germ-plasm, and that consequently these must be reduced in number in the sexual cells to escape the extraordinary complexity which would arise if the ancestral germ-plasms were doubled at each sexual fusion. As the longitudinal division of the chromosomes divides them into two equal halves it is obvious that this will not reduce the number of ancestral germ-plasms, and therefore Weissman predicted that a transverse division of the chromosomes would be found to take place by which the reduction would be brought about. This was soon discovered to be the case for many animal cells, the reducing division taking place during the formation of the sexual cells, but in plants this was not so easily determined. Belajeff, Dixon, Atkinson, and others maintained that a true reduction division took place in the cases examined by them; but the majority of observers, Miss Ethel Sargant, Strasburger, Farmer, Mottier, and many others, maintained that there was no transverse division, but that all the divisions were longitudinal. Recently, however, Farmer and Moore have re-investigated the whole sequence of events in both animals and plants, with the result that a true reduction division is found to occur in the heterotype stage. In many investigations which have recently appeared this transverse division is confirmed, but the exact details of the process are not yet agreed upon. Farmer and Moore state that the spireme thread first becomes longitudinally split, the two longitudinal halves then fuse again, and subsequently bivalent chromosome loops are formed which divide transversely in the middle, and so produce two monovalent chromosomes which pass to opposite poles of the spindle, as already described. Gregoire, on the other hand, states that the threads at the first sinapsis become approximated together and then fuse; the double thread thus produced breaks up into chromosomes, which are thus bivalent in a different sense from those of Farmer and Moore, the monovalent chromosomes being produced by a longitudinal splitting of the thread, which divides it into the two original halves which fused together.

Which of these two methods will ultimately be found to be the correct one remains to be seen, but Allen has recently published an account of the process as it occurs in *Lilium canadense,* in which he agrees substantially with Gregoire, and states definitely that the first appearance of the double nature of the thread is not due to a longitudinal splitting of a single thread, but to an approximation of two threads, which ultimately fuse together to form a single continuous thread in the nuclear cavity. This thread at a later stage undergoes a longitudinal splitting, possibly into those which formerly united; but this is not certain. The double thread then divides up into segments, the chromosomes, and in the subsequent series of events the longitudinal halves of these chromosomes become distributed to the opposite poles of the spindle. Each chromosome is thus seen to be bivalent; but whether each half of the chromosome is to be regarded as a monovalent chromosome is doubtful, as the fusion of the original threads was complete, and there is no means of deciding as to how far the subsequent longitudinal division of the completely fused thread separated it into its two original parts.

Sinapsis.

The term "sinapsis" was first given by Moore to that stage in the prophases of the nuclear division of the sexual cells in which the contraction of the nuclear thread around the nucleolus at one side of the cavity of the nucleus takes place. If this phenomenon is not a result of the action of the fixing reagents, then it indicates some striking change in the metabolic activity of the nucleus. This activity is seen in the increased staining capacity of the chromatin thread and in the changes which take place in the nucleolus, by which it becomes very irregular in shape and closely connected by threads to the chromatin network. In many cases the nucleolar substance appears as if being drawn out into the threadwork, and the nucleolus appears as if some active change were taking place in it.

It is very difficult to escape the conclusion that we are here dealing with a series of changes in the chromatin thread which are intimately bound up with the activity of the nucleolus, and it is probable that the increased stainability of the chromatin is due to an actual transference of a portion of the nucleolar substance into the thread.

Experimental Observations on the Activities of the Nucleus.

So far as I know no experimental investigations into the causes which bring about the changes in the prophases of nuclear division have been made, but it is not difficult to imitate artificially some of the phenomena observed. Olive oil is shaken up in a mixture of methylated spirit and water of such a strength as will allow the oil globules to float. A shallow Petrie dish, three or four inches in diameter, is then taken; the mixture of oil and dilute methylated spirit is well shaken until the oil is broken up into very fine globules, and the mixture is at once poured gently into it. The appearance of the mixture is that of a homogeneous mass of small oil globules distributed through the solution, and can be compared to the granular appearance of a nucleus in a resting stage. The spirit at once begins to evaporate, and currents are at once set up in the solution in such a way that the globules of oil gradually become restricted to certain areas only, and a coarse granular network is formed somewhat like the early stages in the aggregation of the chromatin granules into a spireme in the nucleus. The network gradually becomes more and more clearly defined, and then, just as is the case in the nuclear network, it begins to show a double row of granules, which finally becomes very clear and distinct. The threads become shorter and thicker and break up into irregular lengths, which gradually mass themselves together into an irregular heap or heaps of fusing-oil globules either in the middle or at the periphery of the petrie dish. We have, in fact, a good imitation of the earlier stages in the prophases of division of the nucleus, and it seems not unlikely that the aggregation of oil globules in our petrie dish may afford some clue as to the possible means by which the aggregation is brought about in the nucleus.

I do not suggest that the complex phenomena which take place in nuclear division are to be explained as due simply to such phenomena as diffusion, surface tension, and the like, or any other physico-chemical processes. We must be very careful not to attempt to force merely physico-chemical explanations upon such phenomena as these. Without admitting the necessity of anything akin to a special vital force, we are compelled to admit that vital phenomena do not at present admit of a merely mechanical explanation. But it does seem to me possible that the metabolic activity of the nuclear material at this stage may be accompanied by phenomena referable in part to these agencies. If, for example, active metabolic activities are set up between the nucleus and cytoplasm through the nuclear membrane, as seems probable, it is quite conceivable that this would bring about diffusion currents which might be taken advantage of in producing the aggregation of the more solid parts of the nuclear substance into a more or less definite thread-like structure and its aggregation into chromosomes. In any case such possibilities must be taken into account in considering the significance of such nuclear re-arrangements, and if any of them can be definitely explained in this way the final solution of the problem may be much simplified.

Validity of Cell Structure as seen in Fixed and Stained Preparations.

Our knowledge of the minute details of cell structure and nuclear differentiation depends upon the appearances presented by cells which have been fixed in various reagents and subsequently stained, and it is not an easy matter to determine in how far these are artificial and in how far they are actual structures existing in the living cell. The researches of Fischer, Hardy, Mann, and others have shown that on the precipitation of proteids by reagents structures are produced which were certainly not present originally, and which resemble those often observed in fixed cells. From a consideration of such facts it has been suggested that many of the details revealed in fixed cells, such as centrosomes and centrospheres, with their fibrillar radiations, are produced artificially and have no real existence. It is unfortunate that so little attention has been paid to the examination of living cells, for the structures which can be seen in them are, so far as they can be revealed by the microscope, always like those seen in fixed preparations.

Differentiation of Structure Visible in the Living Cell.

The amount of differentiation visible in the living cell in favourable objects is very considerable. Not only can chloroplasts, starch-grains, nucleus, leucoplasts, pyrenoids, &c., be clearly seen, but also a very considerable amount of detailed structure. Chromosomes have been seen in the living cell by many observers—Treub, Strasburger, Behrens, Zacharias, and others. The series of figures published by Strasburger of nuclear division in the staminal hairs of Tradescantia show the whole process of chromosome formation and separation into two daughter-groups, except the longitudinal division.

In the same object Demoor and de Wildeman have also been able to detect the spindle fibres and connecting fibres. These were not seen by Strasburger; and Zacharias, who has more recently made observations on staminal hairs, was also not able to detect them. Nevertheless Strasburger mentions that in some cases connecting threads were visible at a late stage in the division between the daughter-nuclei, and Treub also describes a similar phenomenon in some cases during the nuclear division in the ovules of an orchid.

In Spirogyra, Strasburger has given a full account of nuclear division in the living cell. Large species of this alga are very favourable objects for this work, and he has shown that in such species the spindle figure as well as the connecting fibres can be seen in the living cell. Wildeman has also seen and figured them; but Behrens states that spindle fibres and connecting threads are not visible in Spirogyra during life.

My own observations upon a large species of Spirogyra which I have had an opportunity of investigating entirely support the view that these structures are visible in the living condition.

The Structure of the Chloroplast.

In view of its extreme importance in the function of assimilation a knowledge of the structure of the chloroplast is important. Owing to its small size a satisfactory demonstration of its finer structure is very difficult. That it consists of a colourless ground substance, in which the chlorophyll is embedded, is clear; but how these two substances are united and the relations between them structurally are not known. Pringsheim concluded that the ground substance of the chloroplast is a sponge-like network with the oil-like solution of chlorophyll in its meshes.

Schmitz thought that the fine granular appearance of the chloroplast was due to a fine net-like structure in which the chlorophyll was diffused. Fromman also describes it as a green granular network. Schwartz, on the other hand, describes it as composed of a ground substance containing a number of green fibrillæ side by side, which are coloured green throughout, but show also an accumulation of the green colouring matter in the form of granules along these threads.

Meyer thought it was composed of a homogeneous ground substance with various-sized granules of the green substance embedded in it. To these granules he gave the name of "grana." Schimper stated that it was composed of a colourless stroma containing numerous vacuoles filled with the green semi-fluid chlorophyll, identical with the "grana" of Meyer.

Some observers consider that the chloroplast is surrounded by a distinct membrane; whilst others consider that the substance of the chloroplast is directly connected by colourless strands to the cytoplasm.

According to some observations which I have made recently, the chloroplast, when examined under high powers in the living condition, appears to be filled with a mass of green granules with a colourless substance between them. But in certain cases a distinct fibrillar arrangement of the chlorophyll is observed. This is very easily seen in the chloroplasts of Euglena, both in the living condition, and, more easily, when the cells are burst and the chlorophyll grains are extruded into the water. But it may be seen also in the chloroplasts of the higher plants when these are large enough to be examined easily. In these cases the green colouring matter appears granular when the chloroplast is in the epistrophe or shade position, fibrillar when it is in the apostrophe or intense light position. This difference in the appearance of the chlorophyll accompanies a difference in the shape of the chloroplast. As is well known, the chloroplast in the epistrophe position presents an oval or more or less circular form; in the apostrophe position a flattened and lenticular form. The fibrillar structure appears to be that of fine fibrils lying more or less parallel, but a closer examination shows that they are connected together here and there so as to give the impression of an elongate network. In the epistrophe condition the chlorophyll corpuscle appears greener than in the apostrophe condition. The granules are in fact so arranged and so numerous as to present a practically continuous surface of chlorophyll to the action of the light rays. The fibrillar arrangement, on the contrary, has numerous light spaces between the fibrils, so that less surface of chlorophyll is exposed to the rays of light. The difference in the amount of chlorophyll surface exposed to the light appears therefore to be bound up with the difference in the intensity of light which causes the different positions of epistrophe and apostrophe to be assumed by the chloroplast. Just as in diffuse light the chloroplasts themselves are more fully exposed to the light than in intense light, so in the individual chloroplast we appear to have such an arrangement of the chlorophyll that in diffuse light a larger surface of it is exposed to the light rays than in a more intense light. The interesting conclusion is therefore arrived at, that the chloroplast is able, not only by its position but also by its structure, to guard itself against the effects of a too intense light.

A careful examination of the chloroplast in the epistrophe position renders it probable that the granular appearance is not due to the existence of separate granules of chlorophyll. It resembles more nearly an optical effect, due to the superposition of alveoli upon one another, such as appears in fine oil-foams. By focusing carefully above and below the granules we get a distinct appearance as of a green alveolar network. If the chlorophyll corpuscle is extruded into water it begins to swell up and becomes vacuolar; the granules disappear and the chlorophyll then appears to be distinctly diffused through the ground substance of the chloroplast. I am therefore inclined to the view that the chlorophyll corpuscle consists of a ground substance in the form of a delicate alveolate structure, in which the chlorophyll is more or less uniformly diffused. The diameter of the threads of this network is greater in the epistrophe than in the apostrophe position, and this affords a means by which the chloroplast can accommodate itself to varying intensities of light.

The chloroplast must be regarded as performing at least two functions. It brings about the dissociation of CO_2 and it is a starch-forming organ. In the algæ and some other plants these two functions appear to be differentiated, and starch is formed directly by the pyrenoid. How far these two functions are independent in the ordinary chloroplast is not known; but that starch can be formed, independently of chlorophyll, in the leucoplasts and in the ordinary chloroplasts directly from sugar and other organic solutions in the dark seems to indicate that the two are not necessarily connected.

The colourless stroma of the chloroplast gives a distinct and pronounced reaction for phosphorus when treated according to Macallum's method. It resembles, therefore, in this respect the nuclein constituent of the nucleus. What the exact significance of the presence of phosphorus in the chloroplast may be I do not know, but it is extremely interesting to find that in an organ in which a high degree of metabolic activity is always found a substance should be present which is akin to the highly organised nuclear constituents. It suggests an interesting comparison with those plants in which a special starch-forming organ, the pyrenoid, is differentiated.

The Centrosomes and Centrospheres.

A vast literature has grown up in connection with the structure and function of these bodies because of the special importance which has been attached to them as the originators of the process of nuclear division and of the formation of the spindle, and because of the important part which it is assumed they play in the phenomena of fertilisation.

Their very general occurrence in animal cells and their prominence in the reproductive processes led plant cytologists to predict that they would be found to occur also in plant cells. But their prediction has not been fulfilled. They are frequently found among the Thallophytes and Bryophytes, but in the higher plants the evidence is steadily accumulating against them, and such structures as have been described by Guignard and others are held to be based upon a misinterpretation of the facts observed.

Where the centrosome exists it consists of a deeply stained granule or group of granules surrounded by radiating fibres. In some cases, as in the Basidiomycetes, the centrosomes only become definitely visible as minute dots at the poles of the spindle, and are not visible until this is completely or nearly completely formed. In other cases, as in Dictyota (Mottier), Ascomycetes (Harper), the centrosomes with their radiations are clearly visible at two opposite sides of the nucleus in the resting stage, and are in close contact with the nuclear membrane. In the Ascus, Harper has shown that the centrosome is in close contact, not only with the nuclear membrane, but also with the chromatin net, and it seems probable that there may be a connection between them. The spindle fibres are formed both in Dictyota and in the Ascus in the nuclear cavity before the nuclear wall breaks down. In the division of the daughter-nuclei the centrosome which is carried over with each daughter-nucleus appears to divide—but this is not certain—to give two new centrosomes for the formation of the new spindle figure.

Experiments on the Production of Artificial Asters.

There are two main views as to the nature of the spindle and astral fibres: (1) that they represent a definite morphological differentiation of the cytoplasm which possesses in itself the power of forming these fibres; (2) that they are formed out of the cytoplasm by some modification of its structure or arrangement of its parts, or by the precipitation or condensation of some of its constituents.

The aggregation of granules into radiating fibrils can be imitated artificially by allowing a drop of alcohol or turpentine to fall upon smoked glass. If the drop is allowed to fall from a good height, we get the artificial centrosomes with radiations first described by Henking; these are due mainly to the splash of the drop and its breaking-up into small particles which radiate outwards, carrying portions of the smoke film with them. If the drop is allowed to fall more gently, so that it does not splash, its first effect is to produce a clearly circumscribed circular ring, and then, by slowly spreading outwards, to produce an aggregation of the smoke particles into fibrils which more nearly represent the appearances produced in cytoplasm than do Henking's splashes.

By careful manipulation we can get in this way representations of the centrosome or centrosphere, or even the radiations around the nucleus. If the edge of the alcohol or turpentine be carefully examined under the microscope as it is slowly spreading outwards, a violent motion of the smoke particles will be observed as soon as the liquid comes into contact with them, and as the liquid passes on these particles settle down into definite continuous fibrils, which go on growing as the liquid continues to spread.

Fischer has described the formation of artificial asters by two methods: (1) If pith is injected with proteid and then fixed, asters are found around small particles of foreign matter in the proteid. (2) If a small granule of corrosive sublimate or a drop of osmic acid be brought into a proteid solution radiating striæ are formed in it by precipitation. He suggests that the centrosome is formed by the precipitation of albuminous substances in living cells by the excretion of nucleic acid from the nucleus, and that, as in (1), artificial radiations are formed around it by the action of the fixing reagents; or possibly by the fixative action of the nucleic acid itself. Or the centrosome itself may produce them, as in (2), by acting as the precipitating agent, just as corrosive sublimate or osmic acid. Mr. Jenkinson has recently described some interesting experiments on the artificial production of asters, and comes to the conclusion that osmotic pressure and surface tension are probably concerned in the formation of these structures in the living cell. The centrosome may be a body capable of withdrawing water from the cytoplasm, of swelling up and dissolving in the water so absorbed, and then giving off radial outgrowths which precipitate the proteids of the cell, and so form astral rays; or the centrosome may undergo decomposition, or may secrete a ferment which would have the same effect upon the cytoplasm.

The Blepharoplast.

The blepharoplast is a special organ associated with the formation of the cilia in motile spermatozoids and zoospores. It consists of a centrosome-like granule, often surrounded by radiations. It appears inside the cell in close relation to the nucleus, or sometimes at the periphery of the cell. In Polytoma the two cilia thus arise from a granule (blepharoplast) at the extremity of the cell. In Ædogonium the blepharoplast arises, according to Strasburger, in the plasma membrane. Strasburger considers them as kinoplasmic in nature, and thus brings them into relation with his other kinoplasmic structures, the centrosome and spindle.

Some authors consider that the blepharoplast is a true centrosome, or homologous with a centrosome. It has not, however, been conclusively shown that it at any period in its history performs the function of a centrosome, or that it is derived from one. Further, in many of these plants, if not all, there are no centrosomes at any stage in their life-history.

On the whole the evidence is distinctly against the view that the blepharoplast is genetically connected with the centrosome. It is more in accordance with the present state of our knowledge to consider the blepharoplasts as special structures which arise *de novo* in the cell for the special function of cilia formation.

The Coenocentrum and its Function.

In the oögonia of some fungi there appears at an early stage in the development of the oösphere a dense granular, deeply stainable substance, the function of which is unknown. It appears in the centre of the cell, and was first discovered in the oösphere of *Cystopus* (*Albugo*) *candida.* It is probably formed by an accumulation of stainable granules or microsomes. It disappears soon after fertilisation takes place, and is therefore not a permanent organ of the cell. Shortly after its appearance one of the nuclei out of the large number irregularly scattered through the oögonium comes into contact with it, and gradually becomes more or less embedded in it. All the other nuclei pass to the periplasm, leaving this single nucleus as the nucleus of the ovum. The fertilising tube which contains the male nucleus also grows towards it, and comes close to it to discharge the male nucleus upon it. This indicates that it may exert in some way or other an attraction, first upon the female nucleus, and secondly upon the fertilising tube, thus helping to bring the sexual nuclei together. Stevens suggests that it may be of the nature of a dynamic centre, and he gave it the name *coenocentrum.* It may be nutritive in function, and may exert a chemotactic stimulus upon the sexual nuclei.

It does not appear to be actually concerned in the fusion of the sexual nuclei. In *Peronospora parasitica,* for example, it completely disappears before the fusion of the nuclei takes place. So far all the views as to its function are purely hypothetical. It may be a mere coincidence that it should become associated with the sexual nuclei at the time they come together in the oösphere. Its function may be totally unconnected with these. From the fact that it stains so deeply in nuclear stains, the substance of which it is composed may be of the nature of nuclein, and it is possible that it may be due to a substance secreted by the nuclei of the oögonium for some special purpose connected with the maturation of the oöspore. It is possible that it may have something to do with the formation of oil, which appears in such abundance in the ripe oöspores. It begins to disappear just at the time the oil begins to form.

It seems more likely that the function of the cœnocentrum is connected with those metabolic activities of the zygote, which must at this stage in its development be very considerable, than with the exertion of an attractive influence upon the sexual nuclei. It is difficult to see how such a selective chemotactic stimulus could be exerted as to act upon one nucleus only out of the large number in the oögonium. But the evidence before us does not admit of any definite solution of the problem at present. The subject demands further investigation of such a kind that a comparative study of the formation and disappearance of the cœnocentrum, the formation of the oil reserves, and the changes in the nuclei, should be carried on side by side.

The Nuclei of the Lower Plants.

The presence of nuclei in the algæ and fungi had already been recorded by Nägeli and many other observers shortly after the discovery of the nucleus by Robert Brown, but it is doubtful whether all the structures described as nuclei by these early observers were really so. It is only in comparatively recent times that it has been possible to determine with any degree of certainty that the minute deeply stainable bodies described more especially by Schmitz (1879) could be regarded as nuclei. This determination was easily made for many of the algæ, especially by the researches of Strasburger, who described both the structure and mode of division. But among the fungi the structure and mode of division of the nuclei were practically unknown twenty years ago, and we have the opinion expressed by De Bary in 1887 that the satisfactory discrimination of true nuclei from other small bodies contained in the protoplasm can only be obtained after renewed investigation.

Previous to 1887 cases of karyokinetic division in fungi had been described by Sadebeck (1883), Strasburger (1884), Fisch (1885), and Eidam (1887). Hartog (1889) described a process akin to karyokinesis in the Saprolegnieæ, and at the end of that year a true process of karyokinesis was shown to occur in Peronospora. Since that time our knowledge of the process of nuclear division in the fungi has been largely extended, and the phenomenon has now been found to be of general occurrence in the group, and many of the forms are unusually favourable objects for the study of the process.

The only groups of plants in which true nuclei have not been found are, so far as I know, the bacteria, Cyanophyceæ, and the yeast fungi. In the yeast plant there is a large homogeneous spherical body which gives the reactions of chromatin similar to the chromatin of true nuclei. With this is associated a prominent vacuole which contains a more or less amorphous substance of a chromatin nature. The two appear to be very closely related and undergo division simultaneously.

The Cell Structure of the Cyanophyceae.

It is easy to demonstrate in the living cell of the Cyanophyceæ that the contents are differentiated into two distinct regions: (1) an outer layer containing the colouring matter; and (2) a central colourless portion which is known as the central body. The central body is considered by many investigators to be a true nucleus. It contains a deeply staining granular substance which to some extent resists the action of digestive fluids, and is therefore similar to the chromatin in the nuclei of the higher plants. In 1887 Scott was able to demonstrate a reticulate structure in this body, and also saw some indications during its division of a process akin to karyokinesis. Zacharias also in the same year, largely on micro-chemical grounds, concluded that it was a nucleus. The problem has been the subject of investigation by numerous observers since that date with very varying results. These results may be shortly summarised as follows:—The central body is not a nucleus (Macallum, Fischer, Massart, Chodat). It is a nucleus of a simple or rudimentary type (Hieronymus, Nadson, Butschli). It is a true nucleus similar to that found in the higher plants, and forms both chromosomes and spindle (Hegler, Kohl, Olive, Phillips).

The facts of the structure of this body, so far as I have been able to ascertain them by the examination of the cell both in the living and fixed conditions, are that it possesses a vacuolate structure, associated with granules which stain deeply in nuclear stains, resist the action of digestive fluids, give a strong reaction for phosphorus and masked iron, and, further, according to the recent researches of Macallum, do not contain potassium. These qualities are characteristic of nuclein, and there can be, I think, no reasonable doubt that these granules are comparable to the chromatin of a true nucleus.

From a consideration of the facts we at present know concerning the central body we cannot, I think, escape the conclusion that it is of the nature of a nucleus, but one of a simple or rudimentary type. It is not sharply delimited from the surrounding cytoplasm, although it sometimes appears as a vacuolar cavity in the centre of the cell, with a vacuolar membrane around it. It seems to me that we might very well regard it simply as a specialised region of the cytoplasm which possesses a pronounced vacuolation associated with granules of chromatin or with a chromatin network.

The Function of the Nucleus of the Cyanophyceae.

The nucleus of the Cyanophyceæ is very large, much larger proportionally than the nuclei of the higher algæ. It gives also a proportionally stronger reaction for phosphorus. Some observers have considered the large size and prominence of the central body as an argument against its nuclear nature. In the algæ the nuclei are much smaller in proportion to the cell, and in many forms are very difficult to make out. On the other hand the pyrenoids which are present in the cells of Algæ stain more deeply in the nuclear stains, and give a much stronger reaction for phosphorus than the nuclei. In *Prassiola parietina* the pyrenoid is in the centre of the cell, and both in the living condition and in stained preparations is much more prominent than the slightly stained nucleus on one side of it. So, also, in Zygnema there are two star-shaped chromatophores, each with a large pyrenoid in the middle, and between them a small very inconspicuous nucleus.

My view is that the large size of the central body in the Cyanophyceæ may be connected with the development of the chlorophyll assimilation; that it may be held to function both as a pyrenoid as well as a nucleus, and that this receives support from what is observed in the coloured bacteria, in which the cytoplasm contains a more abundant supply of chromatin granules than do the colourless bacteria.

Structure of the Bacterial Cell.

Owing to the small size of the bacterial cells it is very difficult to arrive at a correct interpretation of the structures observed. The examination of the larger forms, such as the various species of Beggiatoa, Chromatium, *Bacillus anthracis, Bacillus subtilis,* &c., has, however, revealed a certain differentiation, which enables us to come to some conclusions as to their actual structure. Ernst has shown that the contents of these cells are not homogeneous, as was formerly thought to be the case, but show a differentiation into a less stainable substance, and embedded in it one or more deeply stained granules.

Butschli has shown that the central portion of the contents of the cell exhibit a foam structure in which granules of a chromatin nature are embedded: this is surrounded by a thin layer of a less deeply stained substance, which sometimes accumulates more prominently at the ends of the cell. The central, more deeply stained, froth-like structure with its granules is the nucleus; the delicate peripheral layer is the cytoplasm. From a recent examination which I have made of *Beggiatoa alba, Beggiatoa roseo-persicina, Bacillus subtilis,* and other smaller species, I cannot agree with Butschli that there is a differentiation into a central body or nucleus, and peripheral cytoplasm. In the various species of Beggiatoa and Spirilla which I have examined the cell contents exhibit a reticulate or foam structure of the cytoplasm in which one or more deeply stained granules may be embedded. As these granules stain deeply in nuclear stains, and also give a reaction for phosphorus, they are probably similar to chromatin. They are distributed throughout the whole cell, and are not specially confined to one place.

We must conclude that the bacteria do not contain anything which can be individualised as a nucleus, but that the nuclein constituent of the cell when present is contained in granules distributed throughout the cytoplasm.

The Evolution of the Nucleus.

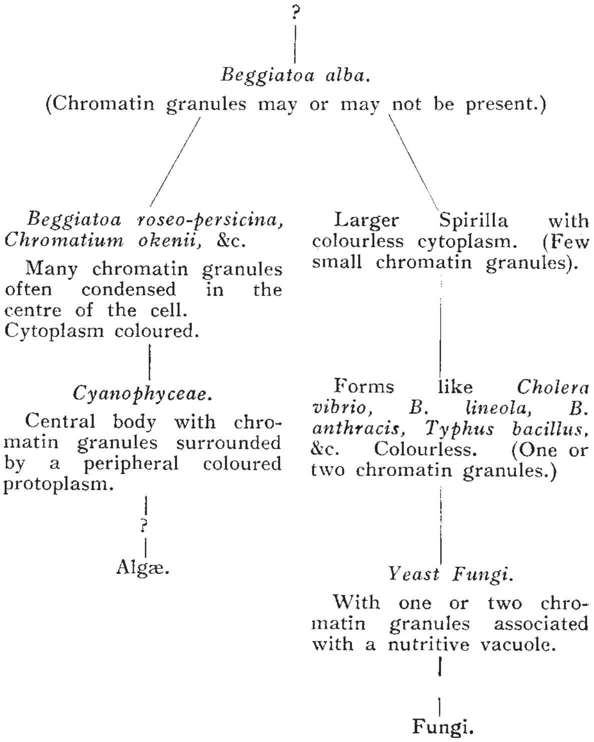
All plant nuclei, from the algæ and fungi upwards, present a striking similarity both in structure and mode of division. The same appears to be true of the animal kingdom, from the protozoa upwards. But among the protozoa on the animal side, and the yeast fungi, bacteria, and Cyanophyceæ on the plant side, there is a kind of border kingdom in which occur structures which appear to represent the nuclei of the higher organisms, but are so different from them in many respects that it is very difficult to say whether they should be regarded as nuclei or not. As we have already seen, the central body of the Cyanophyceæ and the chromatin granules of the yeast plant and bacteria may represent simple or rudimentary forms of nuclei. It is, therefore, possible that we may obtain from them a clue or indication of some kind as to the origin of the nucleus and the process of its evolution.

It is among the protozoa that we find the greatest variation both in form and structure of these rudimentary nuclei. All the various parts of the nuclei of the higher animals can be recognised in them, but, as Calkins points out, are rarely present in one and the same nucleus. From a consideration of the various types Calkins considers that the most primitive nucleus is probably a single mass of chromatin without membrane or reticulum. By the division of this into granules, their association into lines forming primitive chromosomes, the development of a linin network, and the formation of a definite nuclear membrane was gradually brought about the development of the typical nucleus.

In the three groups of plants the Cyanophyceæ, bacteria, and yeast fungi it is not possible to recognise all the various parts of typical nuclei as in the protozoa. In none of them do we find a nuclear membrane, nucleolus, chromosomes, or spindle figure, or centrosome. We have nothing very tangible, therefore, to compare with the typical nucleus of the higher plants, and it is no doubt very largely due to this that we have so many contradictory accounts of the nuclear structures in these forms.

At the same time the nuclei of the higher plants pass through stages in their division which more nearly approach in their structure the simple forms with which we are now concerned. Thus the nuclear membrane and nucleolus disappear, and the chromatin network becomes condensed into a number of homogeneous rods or granules, the chromosomes, which lie free in the cytoplasm. There seems to be no reason why we should not consider the simpler chromatin structures in the lower plants in the light of these ontogenetic changes, as we may term them, of typical nuclei, in order to obtain some indication of the origin and phylogenetic development of the nucleus.

We may take the colourless Beggiatoa as a starting-point; not that this form is the lowest, but because its structure is, on account of its size, more easily examined, and because it is connected possibly with the Cyanophyceæ on the one hand and with the ordinary bacteria on the other. From a careful examination and comparison of its structure with that of other low forms we obtain the following diagram, showing their possible relationships as indicated by their cytological structure:—



?

Beggiatoa alba.
(Chromatin granules may or may not be present.)

Beggiatoa roseo-persicina, Chromatium okenii, &c.
Many chromatin granules often condensed in the centre of the cell. Cytoplasm coloured.

Cyanophyceae.
Central body with chromatin granules surrounded by a peripheral coloured protoplasm.

?

Algæ.

Larger Spirilla with colourless cytoplasm. (Few small chromatin granules).

Forms like *Cholera vibrio, B. lineola, B. anthracis, Typhus bacillus,* &c. Colourless. (One or two chromatin granules.)

Yeast Fungi.
With one or two chromatin granules associated with a nutritive vacuole.

Fungi.

In the simplest case the cell of Beggiatoa contains only cytoplasm without, so far as I can see by careful examination with the highest powers available, any differentiation of chromatin grains or structures of a like nature. Neither do I think that we can regard the protoplast as representing a nucleus. As Fischer points out, the idea that the protoplast of the bacteria stains like a nucleus is not correct, and, as I have been able to show, it certainly does not give a phosphorus reaction like a nucleus. It is, in fact, a simple undifferentiated mass of cytoplasm, either homogeneous or at times exhibiting a foam structure. In this cytoplasm a few granules of chromatin may become differentiated, and this is the first indication of the separation of nuclear substance. Whether there are any species of Beggiatoa or other bacteria which are permanently without nuclear granules I do not know, and it will be very difficult to prove it: but the fact that under certain conditions these cells exist without them seems to point to the conclusion that this may be the primary cell structure, as has been surmised by Haeckel and others.

At an early stage in the evolutionary history of the protoplasm, before a typical nucleus was evolved, we appear to have had the development of colouring matter for the function of assimilation, and a bifurcation into the two distinct lines of descent of the fungi and the algæ. This appears to have been accompanied by two distinct lines of nuclear evolution leading respectively to the development of the central body of the Cyanophyceæ and the nuclear apparatus of the yeast plant. The possible lines of development of the nucleus up to the yeast fungi on the one side and to the Cyanophyceæ on the other are clearly indicated in the diagram; but between the yeast fungi and the true fungi, and between the Cyanophyceæ and the Algæ, there are gaps which we cannot bridge at present. It is possible that the evolution of the typical nucleus may have been brought about in the fungi by the more definite association of the nuclear vacuole with the homogeneous nuclear body, possibly accompanied by a vacuolation of the latter, or that the nuclear body itself may have become the nucleus direct by a process of vacuolation and differentiation within itself.

In the case of the Cyanophyceæ I have already shown that the central body is a vacuolar structure associated with granules of chromatin, and that sometimes this vacuolation becomes so pronounced in resting cells that we get an appearance as of a limiting membrane between it and the cytoplasm. The granules run together and become associated in such a way as to simulate the spireme thread of an ordinary nucleus. Further, we have in some Cyanophyceæ a differentiation of a nuclein-like substance in the form of the red granules of Butschli at the periphery of the central body, which may be an early stage in the separation of a portion of its substance to perform the special functions of the pyrenoid. The complete separation of this into a definite pyrenoid and the formation around the remainder of a nuclear membrane would give us a differentiation comparable to some extent to what we find in *Euglena viridis,* where we have a reticulate nucleus which divides by a rudimentary process of karyokinesis, in which, so far as we know, there is no definite formation of chromosomes and no longitudinal splitting.

As to when or how the higher differentiation of the nucleus, with its chromosomes, longitudinal division, and spindle figure, arose we do not know. Possibly a careful investigation of the lower forms of the fungi and algæ and such organisms as Euglena, and especially the protozoa, may throw light upon this difficult problem.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

SIR DONALD CURRIE has promised to give 20,000*l.* to the equipment fund of Queen's College, Belfast, provided an equal sum is raised from other sources. It is understood that a considerable portion of this amount has already been promised.

MR. E. TOWYN JONES, demonstrator in chemistry at University College, Bangor, has been appointed assistant lecturer and senior demonstrator in the department of chemistry and physics of the Pharmaceutical Society of Great Britain.

IT is announced that Mr. Bazil McCrea has given 6000*l.* to found a chair of experimental physics in Magee College, Londonderry, and to provide two scholarships in connection therewith. The gift is conditional upon funds being provided by subscription within six weeks for the erection of a suitable physical laboratory.

WE have received the year-book of the Michigan School of Mines for 1904–5, and an album of views showing the facilities for instruction afforded by the immediate surroundings of the college. Established in 1885, the college is situated at Houghton, in the heart of the great copper mining region of Lake Superior, with the deepest shafts in the world and the most powerful machinery ever employed in mining. The students also have access to the docks, railways, dressing plants, and smelting works. The special facilities for practical training largely account for the success which the institution has attained. There are at the present time 223 students, their average age being 22½ years.

THE metropolitan medical schools will re-open for the winter session on October 2 and October 3, and in many of them inaugural addresses will be delivered. At University College the address will be given on October 2, at 4 p.m., by Prof. Kenwood on "Preventive Medicine: Past and Present"; at King's College on October 3, at 3 p.m., by Prof. Clifford Allbutt, F.R.S., on "Medical Education in London," and an opening lecture on October 4, at 4 p.m., by Prof. Dendy on "The Study of Zoology"; at Charing Cross Hospital on October 2, at 4 p.m., by Sir James Crichton-Browne, F.R.S.; at St. George's Hospital on October 2, at 3 p.m., by Mr. Brudenell Carter; at the Middlesex Hospital on October 2, at 3 p.m., by Dr. R. A. Young; at St. Mary's Hospital on October 2, at 3.30 p.m., by Dr. Wilfred Harris; at the London (Royal Free Hospital) School of Medicine for Women on October 2, at 4 p.m., by Mrs. Bryant, D.Sc.; at the London School of Tropical Medicine on October 10, at 4 p.m., by Dr. Nuttall; at the School of Pharmacy, Pharmaceutical Society, on October 2, at 3 p.m., by Sir Boverton Redwood; and at the Royal Veterinary College on October 2, at 4 p.m., by Mr. W. Hunter. At Guy's, the London, St. Thomas's, and Westminster hospitals there will be no inaugural addresses, but at the first named Prof. Osler, F.R.S., will open the session of the Pupils' Physical Society with an address on "Some Reminiscences of Sir Thomas Browne" on October 12, at 8 p.m.

THE second volume of the report of the Commissioner of Education for the year 1903 has now been received from Washington. The bulky volume of some 1300 pages is largely concerned with statistics, full data being provided concerning every grade of educational institution. Dealing with the income of colleges and universities, the report shows that in the United States the State and municipal aid to higher education during 1903 amounted to 1,591,000*l.*, of which 1,034,000*l.* was granted for current expenses and 557,000*l.* for buildings and other special purposes. The total value of all gifts and bequests reported during the year to the commissioner by universities and colleges amounted to 2,950,000*l.* The three institutions receiving the largest sums for the year under consideration were:—University of Chicago, 487,500*l.*; Harvard University, 351,300*l.*; and Barnard College, 225,600*l.* The universities and colleges in the States of the North Atlantic and North Central divisions continue to receive the greater portion of benefactions, more than 90 per cent. of the total amount being reported by them in 1903. Dr. John Eaton, who was formerly United States Commissioner of Education, contributes biographical sketches of American educational benefactors and of American citizens whose lives were devoted to educational work, and this brightly written section of the volume affords another indication of the way in which the men of wealth in the United States are encouraged by those in authority to interest themselves in educational progress.

THE polytechnics and technical institutes of London will open shortly for the winter session, and the issue of new calendars and syllabuses has begun already. The session of Birkbeck College will commence, we learn from its new year-book, on October 2, when Sir Edward Fry will deliver the inaugural address. Afterwards the class-rooms and laboratories will be opened for inspection, and an exhibition of work will be held in the school of art. The work of Birkbeck College is conducted in close relation with the University of London, courses of study for examinations of the university being provided under recognised teachers of the university. In addition to evening classes in almost every department of learning, there are day courses of work which give instruction in practical and theoretical science, in classics, in modern languages, in commercial subjects, and in English literature. The moderate fees will enable students of limited means to take advantage of the lectures and laboratory work which have been arranged at this central institution. The syllabus of classes at the Sir John Cass Technical Institute has also been received, and supplies gratifying evidence of the excellent provision of scientific and technical instruction which is available in Aldgate. It is satisfactory to find that in addition to systematic courses of lectures, special attention is given to laboratory work with a view to bring home to students the general and fundamental principles of science in association with the work and products with which they are more immediately concerned in their daily life.

SOCIETIES AND ACADEMIES.

LONDON.

Royal Society, July 20.—"A New Formation of Diamond." By Sir William **Crookes,** F.R.S.

Assuming the following data for carbon—boiling point 3870° ab., melting point 4400°, critical temperature 5800°, critical pressure 2320 ats.—the Rankine or Van der Waals formula calculated from the boiling point and critical data gives for a temperature of 4400° ab. a pressure of 16·6 ats. as the melting-point pressure.

Making similar estimates for other temperatures, it appears that above a temperature of 5800° ab. no amount of pressure will cause carbon vapour to assume liquid form, whilst at 4400° ab. a pressure of above 17 atmo-